Fast Pyrolysis and Bio-oil Upgrading (Challenges)

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Bio-oil properties:

40-50% oxygen content is the primary factor causing the negative properties of bio-oil:

- **High acidity**
- **Aging problem**
- **Immiscibility with petroleum-derived fuels**
- **Pungent odor**
- **Low energy density**

Bio-oil upgrading:

Bio-oil

Using Hydrogen

Packed bed reactor

Without Hydrogen

Olefination

Esterification

Thermal Deoxygenation

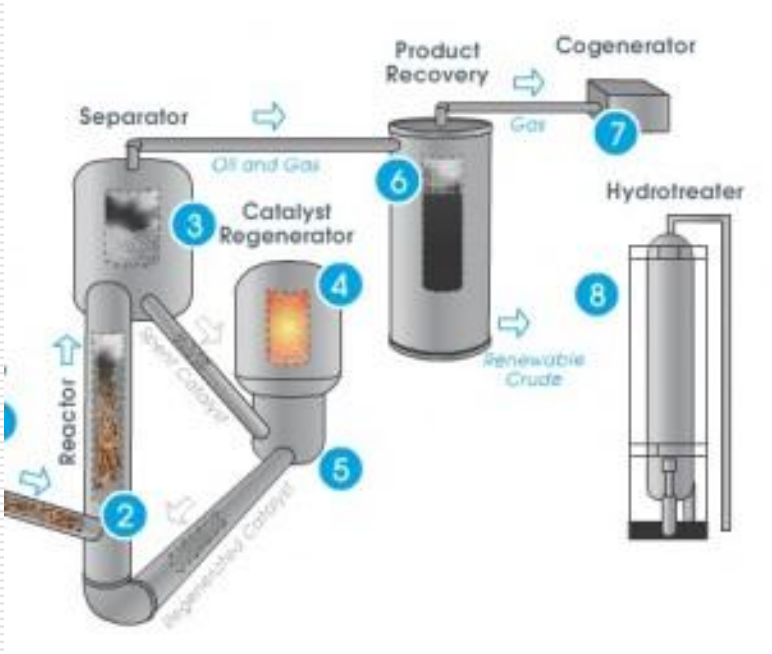
Hydroprocessing with the MSU continuous packed bed reactor:

	Raw Bio-oil	Hydrocarbons
Acid value	98.01	13.37
HHV, MJ/kg	16.08	41.31
Water, %	30.58	1.86
C	36.17	79.00
H	7.84	10.62
N	0.03	0
O	55.96	10.37

Bio-oil upgrading via catalytic pyrolysis :

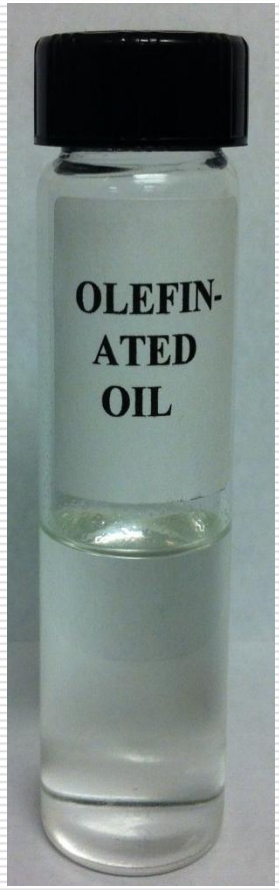
- Catalytic pyrolysis is being investigated by researchers . A hybrid catalytic pyrolysis system at 500 ton-per day is being constructed by Kior in Mississippi. Partially deoxygenated bio-oil is produced by catalytic pyrolysis followed by hydrotreating to produce low-oxygen hydrocarbons.
- Non-hybrid catalytic pyrolysis systems are being investigated by George Huber, Univ. of Mass, and Gas Technology, Incorporated.

Kior hybrid system schematic:



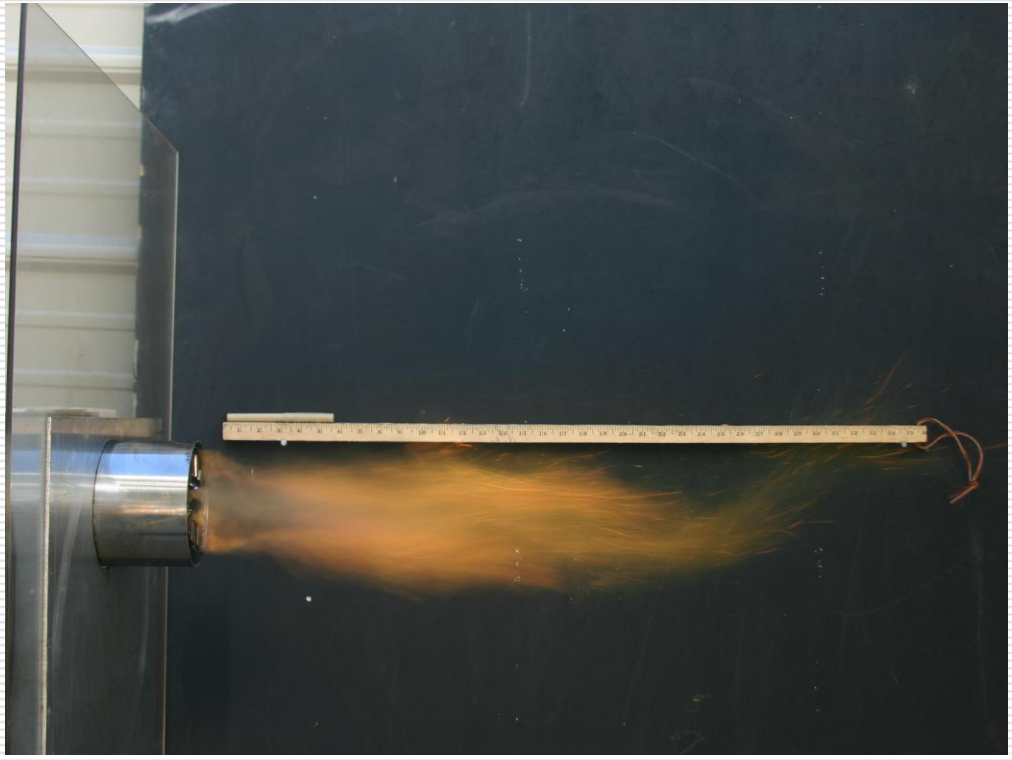
Olefination:

	Raw Bio-oil	Boiler Fuel
Acid value	98.01	19.23
HHV, MJ/kg	16.08	34.01
Water, %	30.58	1.701
C	36.17	71.06
H	7.84	10.0
N	0.03	0.13
O	55.96	18.81



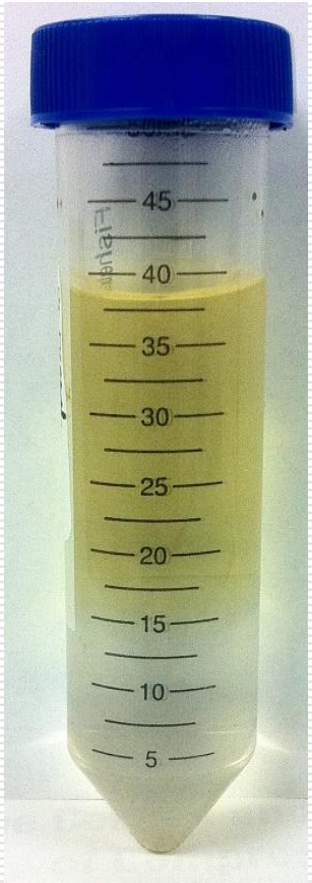
Product testing:

- A highly combustible boiler fuel was produced by olefination as the test below indicates:



Esterification to bio-diesel:

	Raw Bio-oil	Bio-diesel
Acid value	98.01	16.70
HHV, MJ/kg	16.08	36.45
Water, %	30.58	5.3
C	36.17	78.18
H	7.84	9.71
N	0.03	0.41
O	55.96	11.70



Thermal deoxygenation:

	Raw Bio-oil	TDO 1st Stage
Acid value	98.01	22.86
HHV, MJ/kg	16.08	37.17
Water, %	30.58	4.7
C	36.17	79.05
H	7.84	9.22
N	0.03	0.34
O	55.96	11.39

Summary:

- Numerous practitioners are attempting to improve the HDO path to production of hydrocarbons from bio-oil. But technical and cost factors (cost of hydrogen and hydrotreater) persist.
- Catalytic pryolysis in a hydrogen atmosphere is being investigated by research organizations and a hybrid system is being commercialized; however, reported yields are not higher than for HDO of liquid bio-oils and the expense for these pressurized systems is relatively high.

Summary:

- A potential path to several fuel types is catalysis without hydrogen. MSU has successfully produced high-energy boiler fuels; sub-transportation ASTM fuels have been produced that require refinement to meet ASTM fuel standards.
- A likely productive future path for researchers is to produce fuels from bio-oil with little, to no, hydrogen treatment. Given time and research this appears a viable goal with favorable economics for the product fuels.